

Online homework: Does It Make a Difference?

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Readers may have heard of WebAssign¹, CAPA², OWL³ or Homework Service⁴. These are a few of the systems available to automate the process of collecting and grading student homework. Some of you may already be avid users of one of these systems, others may have wondered about using them, and still others might believe it is unconscionable to relegate something as important as homework to a machine. Computer homework systems can be a time-saver to instructors (at least in large-enrollment courses), but whether the students are helped or harmed by the use of the system is another issue.

On the pro side the arguments include the following: (1) automated homework systems permit more practice (quantity and frequency) which encourage students to stay on top of the material; (2) they give immediate feedback and enable students to master the material by correcting their own mistakes; and (3) they eliminate the easiest form of cheating by offering randomized variables in questions for each student to solve. On the con side, (1) the computer (usually) gives no indication as to why a problem might be wrong; (2) multiple submissions could lead students to adapt a trial-and-error strategy instead of carefully thinking through the problem; and (3) simply grading a number tends to put even more emphasis on getting the final answer right by any means without actually understanding the process. These issues are not new—physicists have been experimenting with computer grading of student work for three decades⁵⁻⁸—but they are more important now that the Internet has eliminated many of the technical barriers to using automatic homework systems. To help resolve some of these issues, we have conducted a study of computer-graded homework vs. human-graded homework in large introductory-physics courses. The study compared the performance of students using an online

homework system to those submitting their work on paper in the traditional manner. This note is intended as a practical summary of the results. A more in-depth description is in preparation and should soon be available by contacting the authors.

The bottom line of our investigation is that web-based homework leads to neither a significant improvement nor a significant reduction in student learning: All other things being equal, it doesn't make a big difference whether the computer or a human being is wielding the "red pen". Other factors in a course have a much greater impact on student performance than the *method* of collecting homework and delivering feedback. This supports the viewpoint that technology itself does not improve or harm student learning, but rather that the underlying pedagogy is the critical issue.

The screenshot shows a web browser window titled "WebAssign - sbonham | physics | Netscape". The page header includes "WebAssign.ncsu" and navigation links like "Info", "Guide", "Student Surveys", "Textbook", "Credits", and "Logout". The user information section lists: Name: Student, Joe; School: North Carolina State University; Course: PY 211, section 000, Fall 1999; Teacher: Scott Bonham; Due Date: Friday, Nov 17 2000 2:37 PM EST; Current Date: Wednesday, Nov 15 2000 2:56 PM EST. A message states: "You may resubmit changes in your last response on this page. You have made 1 submissions out of the 3 allowed. These are the scores for the last submission." Below this is a table showing scores for a question with ID 74216. The table has columns for Question ID, Points, and Total. The row for question 74216 shows 2 points and a total of 2. Below the table is a physics diagram of a 6 kg block on an inclined plane at an angle of 18 degrees. The question asks for the acceleration of the block. Two options are provided: "0.028 m/sec^2" (selected) and "2.28 m/sec^2" (marked incorrect with a red X). A "Submit for Grading" button is at the bottom.

| Question ID | Points | Total |
|-------------|--------|-------|
| 74216 | 2 | 2 |

6 kg
 $\theta = 18^\circ$

1. Find the acceleration of the block.

- If friction between the block and the plane is negligible.
 m/sec²
- If the coefficient of friction between the block and the plane is 0.15.
 m/sec²

(Assume that the block is in motion.)

Submit for Grading

Figure 1: Example of homework exercise delivered via the web, showing the standard level of feedback provided by the WebAssign system. (This is the actual question delivered to students, but in a mocked-up assignment to better illustrate the feedback, and to protect privacy of students.)

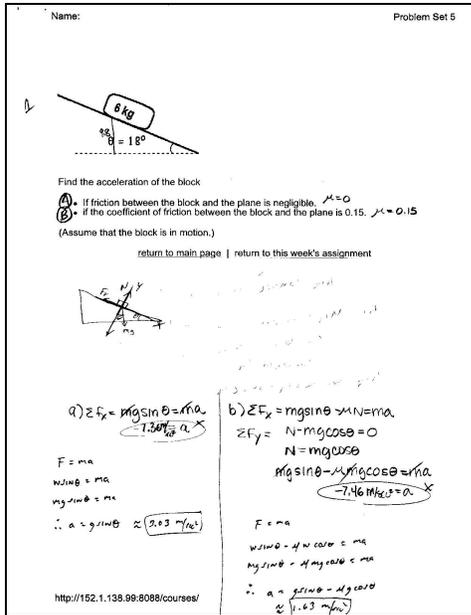


Figure 2: Example of actual written homework problem collected on paper and graded by hand, using same question as Figure 1. The student's work is at the top of each column in the larger letters with final answer circled; the grader has written down the correct solution for each case below with the final answer boxed. This level of feedback from the graduate student grader is uncommon in large introductory physics courses.

This research project was first carried out with two large sections of an introductory calculus-based physics course (~110 students in each section) and then was repeated the next semester with two sections of an algebra-based course (~60 students each). In both courses, an experienced instructor taught the sections back-to-back on the same day, keeping everything as similar as possible—with the exception of the homework method employed. In one section students submitted their work to WebAssign for grading (with resubmissions allowed), while students in the other section turned in their homework on paper to a graduate teaching assistant (TA), who spent 15–20 hours a week thoroughly grading the assignment. An example of a web assignment can be found in Figure 1 and an example of student written work and TA feedback can be found in Figure 2. The respective paired sections received essentially the same assignments, which were mostly composed of standard textbook-type problems. Student learning was measured by multiple-choice and written problems on exams and quizzes, along with the Force and Motion Concept Exam (FMCE)⁹ in the calculus course. Students were also surveyed, and

some were interviewed. Both of these courses were multiple-section courses taught by different instructors in any given semester; students in the other calculus-based sections took the same common exams and received the same web-based assignments.

Student performance was similar between the paper and web sections. The students from the web sections consistently performed slightly better on the tests (calculus, 78% vs. 75%; algebra, 82% vs. 77%), but this difference was not statistically significant—no conclusions can be drawn from it. In fact, differences between calculus-based sections taught by different instructors were greater. Furthermore, the small difference seen in test scores is possibly due to a difference in student ability—in both courses the students in the web section had slightly better GPAs and SAT math scores. When the scores are broken down between written and multiple-choice questions, there are still no significant differences between the two homework methods. A selection of written work from the calculus course was analyzed for differences in how students wrote out the problems (use of equations, words, numbers, units, etc.). The only significant difference found with this data is that the paper group was better at following instructions to box or circle the final answer. The FCI was given to the calculus students at the beginning and end of the semester, and the two sections had nearly identical gains. Looking at the rest of the course, the major significant difference found between paired sections was for the

| Course | Calculus | | Algebra | |
|---|------------|------------|---------|-------|
| | Web | Paper | Web | Paper |
| FMCE gain | 19% | 20% | - | - |
| Test Average | 78% | 75% | 82% | 77% |
| Quiz Average | - | - | 61% | 58% |
| Homework score | 88% | 72% | 63% | 62% |
| Laboratory score | 85% | 84% | 73% | 76% |
| Visits to tutorial center (semester) | 3.7 | 3.3 | 5.3 | 5.8 |
| Time spent at tutorial center (semester) | 3.6 h | 3.5 h | 6.8 h | 8.1 h |
| Time spent on homework/week (hours, self-reported on surveys) | 3.3 | 2.4 | 4.4 | 4.1 |

Table 1: Overview of section performance in this study. Values in boldface are statistically significant, using standard statistical criteria, a p-value less than 0.05 on a two-tailed t-test. (That test is a measure of the probability that the difference is caused by some other effect than the one being studied, and $p < 0.05$ means that there is less than a 5% chance that something other than the homework method is the cause of the observed difference).

calculus section's homework scores—81% vs.76%. The web section may have done better because they had the opportunity to resubmit assignments or, alternatively, because they had three short assignments a week as opposed to one long one like their paper-based colleagues. This difference was not seen in the algebra course, where both sections had one long assignment a week. Also, the scores in the algebra web section might have been depressed because of unusually high levels of technical difficulties during the first few weeks, which caused the instructor and many of the students to develop negative attitudes towards the homework system. No differences were found in laboratory performance or in the use of the walk-in Physics Tutorial Center.

Of course, test and homework scores do not tell the whole story. Students in the web sections reported spending substantially more time on homework than those in the paper sections—an average of 30 minutes to nearly an hour more a week—though it is not immediately obvious whether this is a positive or negative aspect. The calculus web students overwhelmingly stated that they would like to continue to use the web-based homework system, while less than half of their paper colleagues indicated that they would like to continue submitting their homework on paper. Even in the algebra course, during which the web-based system experienced significant difficulties and the instructor was answering angry e-mails at midnight, the students' comments were more supportive than we initially expected, given the situation, and a

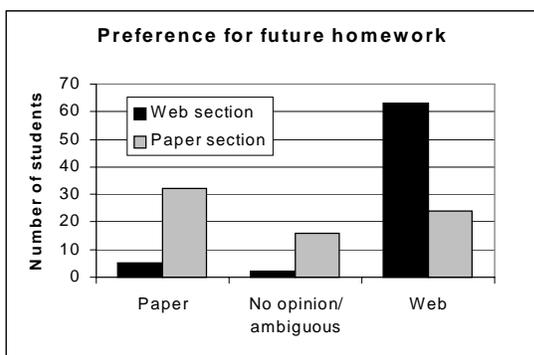


Figure 3: Student responses from survey when asked, "If it were up to you, would you prefer to continue submitting your homework on paper (WebAssign) or instead submit your homework over the Web (on paper)?"

significant number reported that they actually had few or no technical problems with the homework. There was also no indication from the surveys and interviews that many students employed a trial-and-error approach as a common strategy for doing computer-based homework. Most would work their homework out on paper and then enter it into the computer and check their work.

In the case of large-enrollment lecture sections of introductory physics courses with experienced instructors and thorough grading of textbook problems, we can conclude that the **method of collecting and grading homework makes little difference to student performance**. There are some additional points that should be considered:

- The effort involved in grading of the paper exercises in this comparison was much more thorough than typical. All problems on all assignments were graded, including both the process and the final result. Written comments were often given, and occasionally these were extensive. We would expect that feedback by hand or by computer is better than no feedback at all, but to what degree we can not say.
- The resources (money/time) required by using paper vs. computer homework could differ significantly, particularly in large-enrollment courses. In this study, the paper-based sections employed a full-time graduate teaching assistant (15-20 hours/week). The cost of online homework systems ranges from free software (provide your own machine and content) to fully hosted systems with lots of content for several hundred dollars a semester per class. Perhaps the greatest benefit of web-based homework is that it can free up personal or monetary resources which can be devoted to other aspects of the course where they can make a greater difference.
- Although web-based systems did not seem to hinder student performance, technical problems and negative instructor attitude did make the algebra web section a more unpleasant experience than it had to be. Others have observed that having someone available to ensure that things run smoothly has a great impact on

student and instructor attitudes toward the homework system.¹⁰

- Standard textbook-like problems were used in this investigation; to a certain extent, these have been optimized for paper homework. Computers allow us to give types of questions that would not be possible on paper (e.g., Physlet™ exercises¹¹) which could prove to be a decisive improvement over textbook problems—not because of the technology itself, but as a result of better pedagogy enabled by the technology.

Web-based homework is a viable alternative to the traditional paper-based approach. It does not bring significantly greater benefits to students, but neither does it do much worse than standard methods of collecting and grading homework. It probably will help students in courses where homework could not otherwise be assigned. Students generally respond positively to using a computer for homework and, in general, seem to take their assignments seriously. Web-based homework may also allow for more pedagogically sound instruction by freeing up instructor resources for other aspects of the course, or by enabling new kinds of assignments that may be more valuable than traditional paper-and-pencil ones. Technology alone is not going to improve instruction, but web-based homework has a rightful place in the physics instructor's toolbox.

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